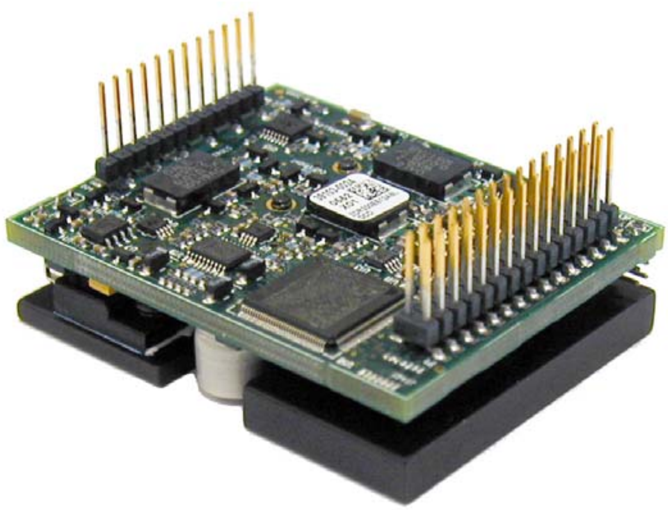
ZDCR300EE User Manual

Rev 1.0



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List of Abbreviations

AC	Alternating Current
CAN	Controller Area Network
CE	Conformité Européenne (European Conformity)
CFM	Cubic Feet per Minute
DC	Direct Current
EMI	Electromagnetic Interference
I/O	Inputs & Outputs
LVD	Low-Voltage Directive
MOSFET	Metal-Oxide Surrounded Field-Effect Transistor
PCD	Printed Circuit Board
PDI	Programmable Digital Input
PDO	Programmable Digital Output
PE	Protective Earth
RMA	Return Material Authorization
RMS	Root Mean Square
RPM	Revolutions Per Minute
VDC	Volts DC

1 Detailed Specifications

1.1 Specification Summary

Table 1

Power Stage Specifications	
DC Supply Voltage	20 - 80 V
Peak Output Current	± 12 A (8.6 Arms)
Maximum Continuous Output Current	± 6 A (4.3 Arms)
Minimum Load Inductance*	250 µH
Switching Frequency	20 kHz
Heatsink (Base) Temperature Range	0 ° to + 65° C, disables if > 65° C
Power Dissipation at Continuous Current	18 W
Internal Bus Capacitance	33 µF
Logic Supply Voltage	5 VDC (+/- 5%) @ 0.4A + current consumption of feedback and I/O
Under-Voltage Limit	17V
Over-Voltage Limit	86 V
Control Specifications	
Commutation Method	Sinusoidal or Trapezoidal (programmable)
Max Encoder Line Frequency	1.25 MHz
Current Loop Sample Time	50 µs
Velocity Loop Sample Time	100 µs
Position Loop Sample Time	100 µs
Mechanical Specifications	
Power Connector: P2	Single row header, 0.1 inch (2.54 mm) spacing
Signal Connector: P1	Dual row header, 0.1 inch (2.54 mm) spacing
Size (L x W x H)	2.5 x 2.0 x 0.73 inches 63.5 x 50.8 x 18.5 mm
Weight	3.4 oz 95.2 g

1.2 Power Stage Specification Details

1.2.1 DC Supply Voltage

Corresponds to the bus voltage of the drive. The drive accepts DC input power only, of which the voltage may vary anywhere within the range of 20 - 80 VDC. As a protection feature, the drive will disable itself upon an under/over voltage. An under-voltage corresponds to ≤ 17 VDC while an over-voltage corresponds to ≥ 86 VDC.

1.2.2 Peak Current

Pertains to the maximum peak current the drive can output according to hardware limitations. The maximum peak output duration is also internally limited to occur for no longer than 2 seconds. An RMS rating can be obtained by dividing this value by $\sqrt{2}$.

1.2.3 Continuous Current

Pertains to the maximum continuous current the drive can output according to hardware limitations. An RMS rating can be obtained by dividing this value by $\sqrt{2}$.

1.2.4 Minimum Load Inductance

The minimum inductance needed at the output of the drive for proper operation. For a brushless motor, this corresponds to the phase-to-phase inductance. If this minimum inductance is not met, a filter card should be used to add additional inductance. Some motors may operate with slightly less than the required inductance if the bus voltage is low enough. AMC provides various accessories including inductive filter cards for a wide range of AMC drives (for more information visit www.a-m-c.com).

1.2.5 Switching Frequency

The switching frequency of the drive output power stage (MOSFET drive).

1.2.6 Temperature Range

The drive operating temperature range. If operated above 65^{o} C, the drive will disable itself. The storage temperature range of the drive is –40^{o} to 85^{o} C. Temperature is measured on the heat sink near the location of the power stage of the drive.

1.2.7 Power Dissipation

The power dissipation of the drive, assuming approximately 5% power loss to heat dissipation. Calculated by taking 5% of P=V*I at continuous current and peak bus voltage.

1.3 Control Specification Details

1.3.1 Commutation Method

The method by which the drive controls the motor phase currents. Trapezoidal commutation is also commonly referred to as brushless DC or 6-step commutation. Sinusoidal commutation is commonly referred to as brushless AC.

1.3.2 Loop Sample Times

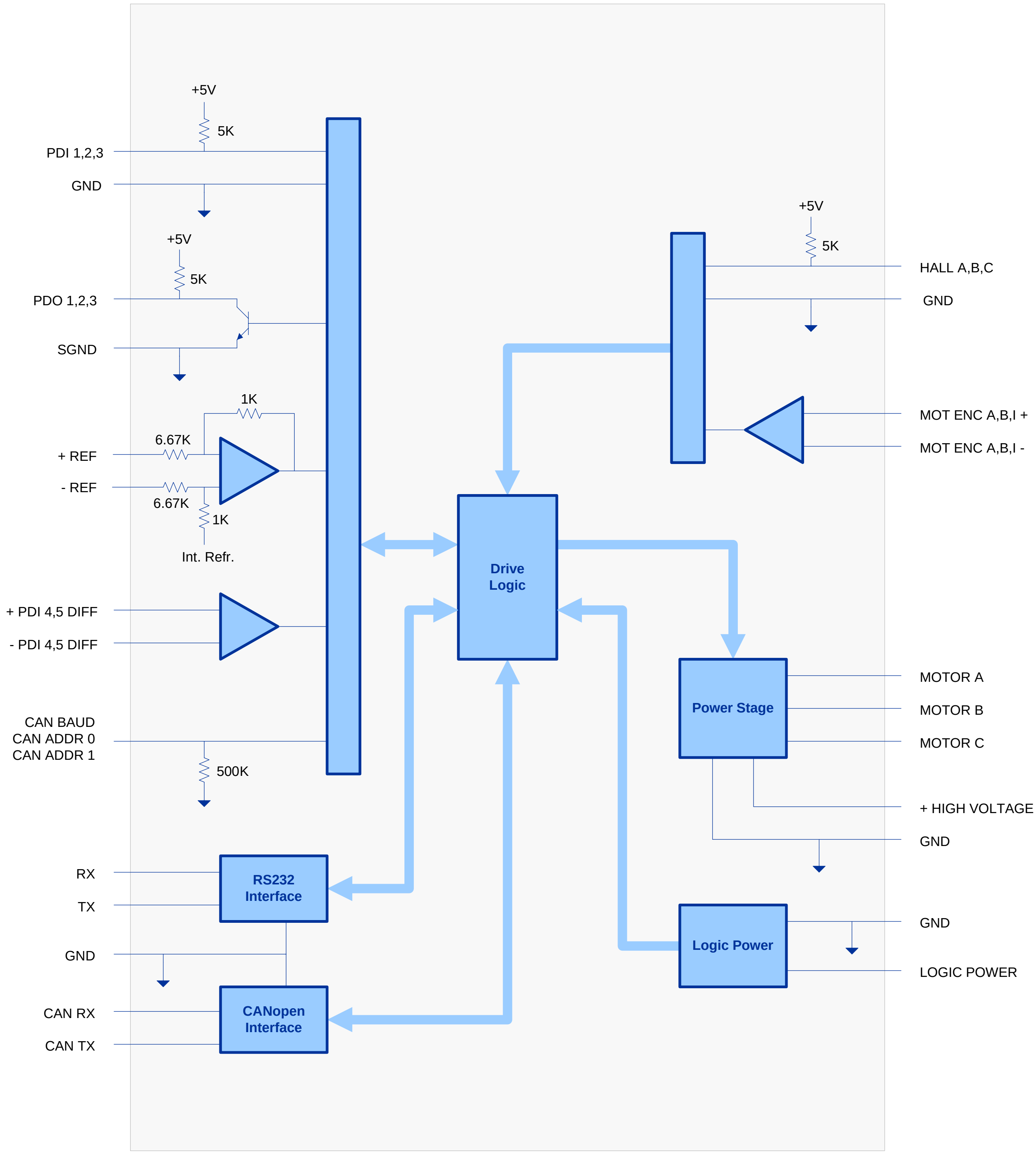
The time interval at which the drive updates the corresponding loop according to the available internal or external feedback. Disturbances that occur more rapidly than these rates will be transparent to the corresponding control loop.

1.3.3 Maximum Encoder Frequency

The highest frequency at which the drive can interpret encoder feedback. This frequency corresponds to (pre-quadrature) encoder lines per second. To convert this frequency to RPM, use the following formula: RPM = (Max Encoder Freq.) $\times$ 60 $\div$ (encoder line count).

2 Block Diagram

Figure 1



3 Connector Information

3.1 Pin Function Summary

Table 2

P1 – I/O Connector				
Pin	**Name**	**Description**	**Section**	**I/O**
1	CAN ADDR 0	CAN bus address selector (0-3 V range).	3.2.1	I
2	CAN ADDR 1			
3	-REF IN	Differential analog command input or programmable analog input.	3.2.4	I
4	+REF IN			
5	GND	Signal ground.	3.2.7	-
6	CAN BAUD	CAN bus bit rate selector.	3.2.1	I
7	PDO 1	Programmable digital output.	3.2.6	O
8	PDO 2			
9	PDO 3			
10	PDI 1	Programmable digital input.	3.2.5	I
11	PDI 2			
12	PDI 3			
13	RX	RS232 receive.	3.2.3	I
14	CAN_RX	CAN receive (requires external transceiver).	3.2.2	I
15	TX	RS232 transmit.	3.2.3	O
16	CAN_TX	CAN transmit (requires external transceiver).	3.2.2	O
17	+PDI 4	Programmable differential digital input, or Step+/Step-, or Aux Enc A+/A-.	3.2.5	I
18	-PDI 4			
19	+PDI 5	Programmable differential digital input, or Direction+/Direction-, or Aux Enc B+/B-.		I
20	-PDI 5			
21	GND	Signal ground.	3.2.7	-
22	HALL A	Hall sensor commutation inputs. Internal 5 kΩ pull-up to +5 V_{DC}.	3.2.8	I
23	HALL B			
24	HALL C			
25	ENC I+	Differential encoder index input. For single ended encoder, leave the I- (P1-26) terminal open.	3.2.9	I
26	ENC I-			
27	ENC A+	Differential encoder channel A input. For single ended encoder, leave the A- (P1-28) terminal open.		I
28	ENC A-			
29	ENC B+	Differential encoder channel B input. For single ended encoder, leave the B- (P1-30) terminal open.		I
30	ENC B-			

For more detailed information on an I/O pin function, refer to the corresponding section as given in Table 3.

Table 3

P2 – Power Connector			
Pin	**Name**	**Description**	**I/O**
1	+5V IN	5V logic supply, +/-5%. Input current is 0.4A + current consumption of feedback and I/O.	I
2 3	POWER GROUND	Power ground (current rating of 3A per pin).	-
4 5	HIGH VOLTAGE	DC power input (current rating of 3A per pin).	I
6	N/C	Not connected.	-
7 8	MOTOR C	Motor phase C connection (current rating of 3A per pin).	O
9 10	MOTOR B	Motor phase B connection (current rating of 3A per pin).	O
11 12	MOTOR A	Motor phase A connection (current rating of 3A per pin).	O

3.2 Pin Function Details

This section describes the pin functions of Table 3 in more detail. For TTL logic I/O, 5 V_{DC} represents a logic high and 0 V represents a logic low (digital signal polarity can be configured via software).

3.2.1 CAN Configuration

The CAN configuration pins are comprised of two pins for CAN bus addressing (CAN ADDR 0 & CAN ADDR 1) and one pin for selecting the CAN bus bit rate (CAN BAUD).

The CAN ADDR 0 and 1 inputs are used to set the CAN node address. The formula below shows the voltages and corresponding address:

$$CANAddress = \frac{7 * Addr0}{3} + 8 * \frac{7 * Addr1}{3}$$

Table 4

CAN ADDR 0 Value (V)	CAN ADDR 1 Value (V)	CAN ADDR Tolerance (V)	CAN Address (Node #)
0	0	-0.000 +0.100	Address stored in non-volatile memory
3/7 (0.43)	0	-0.100 +0.100	1
6/7 (0.86)	0	-0.100 +0.100	2
9/7 (1.3)	0	-0.100 +0.100	3
…	…		…
18/7 (2.57)	21/7 (3.0)	-0.100 +0.100	62
21/7 (3.0)	21/7 (3.0)	-0.100 +0.000	63

CAN ADDR 0 and 1 are integer multiples of 3/7 V, between 0V and 3V. Examples of how to set some CAN addresses are given in Table 4. Note that the CAN address 0 will utilize the address stored in non-volatile memory.

The CAN bit rate is set by applying the appropriate voltage to the CAN BAUD pin as given in Table 5.

Table 5

CAN BAUD Value (V)	CAN BAUD Tolerance (V)	CAN Bus Bit Rate (bits/s)
0	-0.000 +0.388	Bit rate stored in non-volatile memory
1	-0.388 +0.388	500k
2	-0.388 +0.388	250k
3	-0.388 +0.000	125k

3.2.2 CAN Interface

A CAN interface is provided through a transmit pin (CAN_TX) and a receive pin (CAN_RX) which conform to the CAN standard. In order to access the CAN bus an external transmitter, which meets a CAN physical layer standard (ex. ISO 11898-2), is required. This transceiver acts as a medium between CAN chip-level signals (CAN_TX & CAN_RX) and CAN bus-level signals (CAN_H & CAN_L) used on the two-wire differential bus. When choosing a transceiver, make sure it matches with the physical layer standard of the CAN bus being used. It is also recommended to isolate the transceiver from the drive.

3.2.3 RS232 Interface

The RS232 interface of the drive consists of a transmit data (TX) and receive data (RX) pin, often referred to as Tx and Rx. Connect these pins to the appropriate locations on a serial cable connector, as specified by the RS232 standard. The reference point for the RS232 signals is common with the signal ground (GND) of the drive.

3.2.4 Reference Input

12-bit differential analog input with a range of ±10 V. Use with a single ended or differential reference signal (see Section 5.6.1 for wiring instructions). If not needed for a reference input, may be used as a programmable analog input.

3.2.5 Digital Input

Internally pulled high through a current limiting 5 kΩ resistor. Pull to ground in order to activate.

3.2.6 Digital Output

Internally pulled high through a current limiting 5 kΩ resistor. The transistor is turned ON upon activation.

3.2.7 Signal Ground

Signal ground and power ground are equivalent and interchangeable for this drive.

3.2.8 Hall Sensor Input

Internally pulled high through a current limiting 5 kΩ resistor. Connects to the output (open-collector) of a Hall sensor. See Section 5.5.3 for wiring instructions.

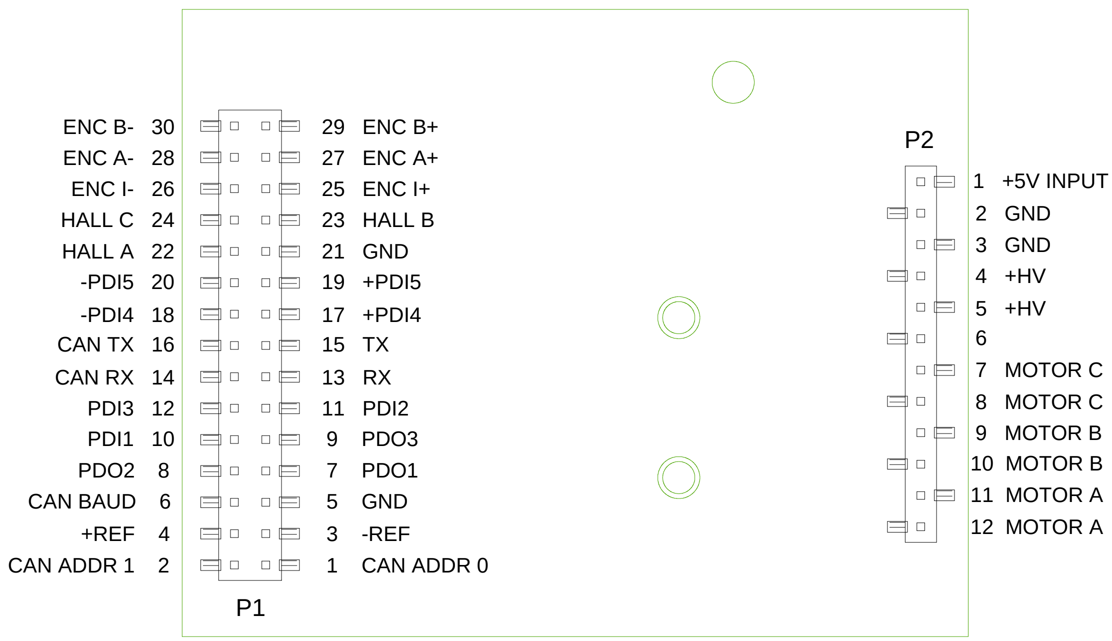
3.2.9 Differential Encoder Input

Used with differential or single-ended encoder outputs. Both channel A and channel B are required, whereas the index channel is optional. See Section 5.5.3 for wiring instructions.

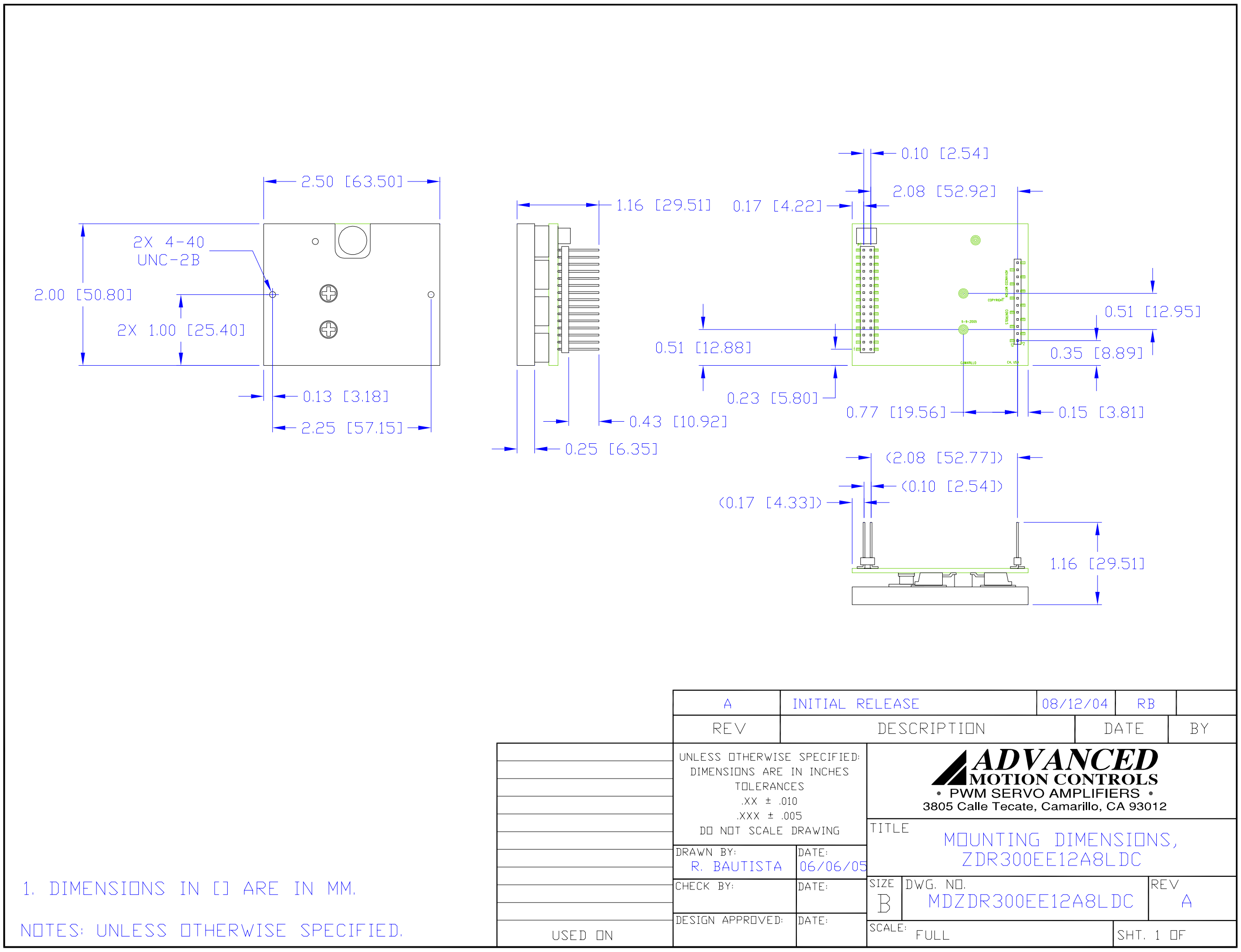
4 Mechanical Information

4.1 Connector Information

P1 – I/O Connector	
Connector Information	Dual Row, 30-pin, 0.1 in (2.54 mm) pitch
Mating Connector Example	Samtec: SSM-115-L-DV
P2 – Power Connector	
Connector Information	Single-Row, 12-pin, 0.1 in (2.54 mm) pitch
Mating Connector Example	Samtec: BCS-112-L-S-PE



4.2 Mounting Dimensions



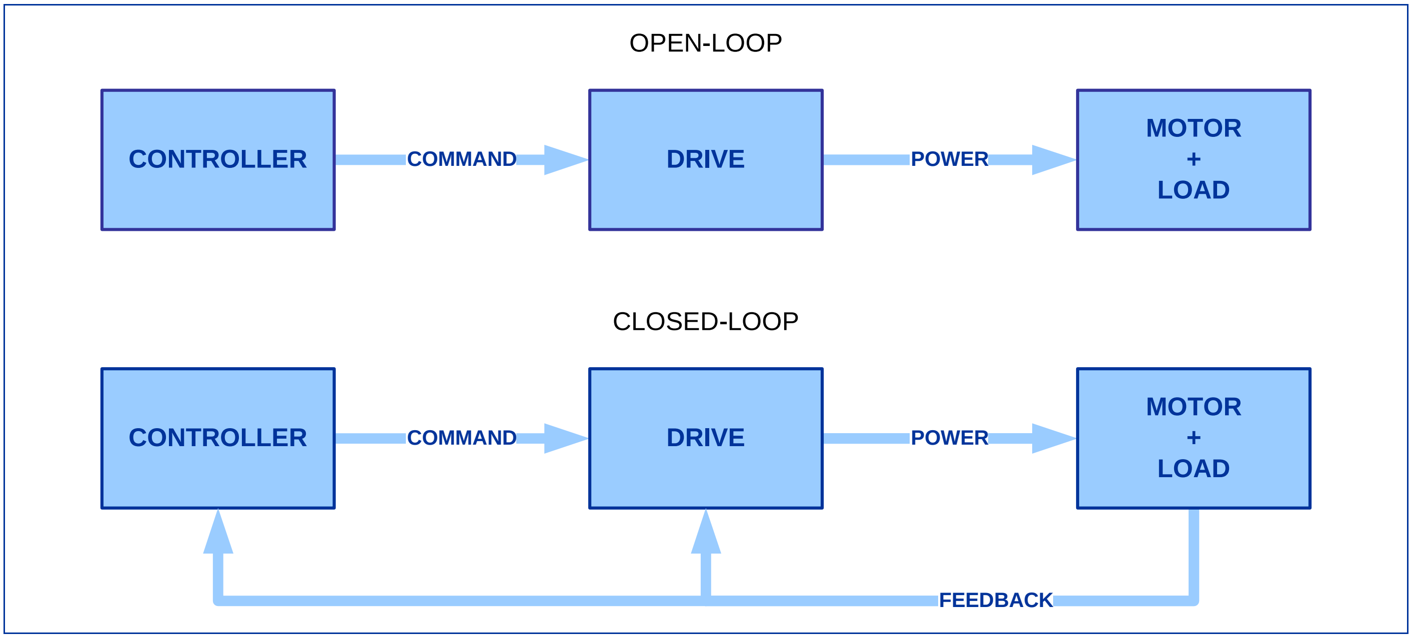
5 WIRING INSTRUCTIONS

This section starts with an overview of servo system wiring and finishes with CE wiring requirements. In general, the main components of a servo system will include a controller, drive, motor, and power supply. Wiring and requirements for all these components are discussed in this section.

5.1 System Overview

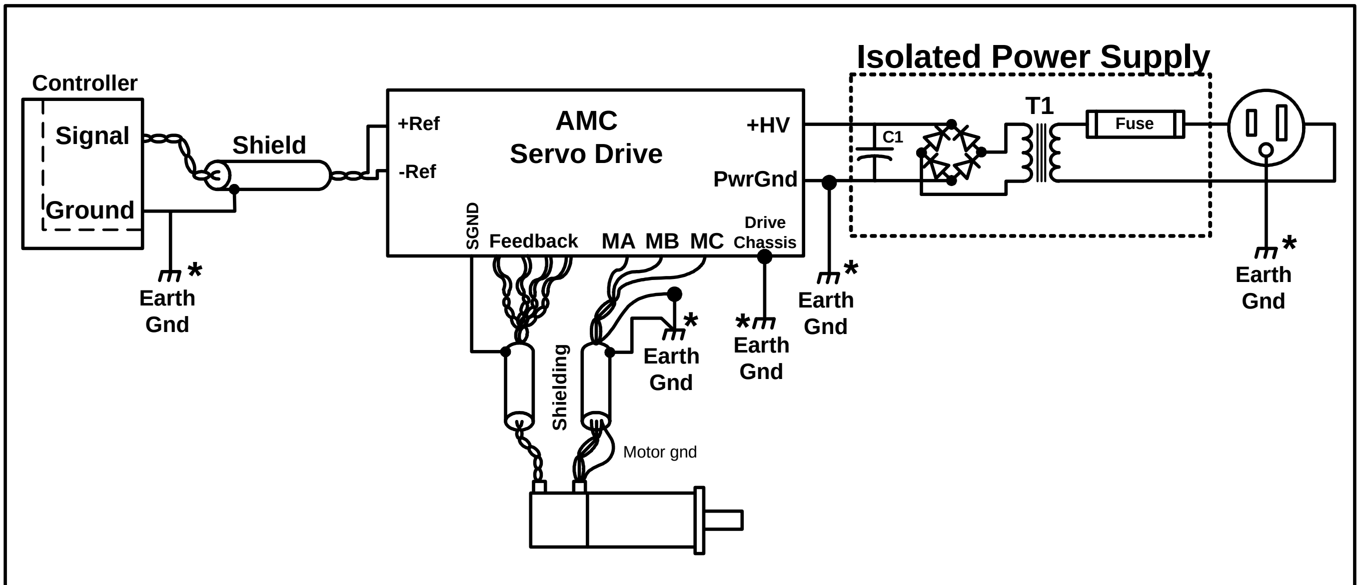
A typical servo system involves a controller, drive, and motor. These components can create one of two different system types: open-loop or closed-loop (see Figure 2). Since open-loop systems have inherent control restrictions, most servo systems tend to be closed-loop. Because a closed-loop system is just an extension of an open-loop system, this document focuses on closed-loop systems without loss of information regarding open-loop systems.

Figure 2



The wiring method for coupling the components of a servo system will depend upon the power supplies used and the isolation available on both the power supplies and the servo components. Since this manual is for a non-isolated drive with DC power input, only this scenario (see Figure 3) will be covered.

Figure 3



Brushless Motor Wiring Diagram With Isolated Supply and Differential Reference Input

* These connections should each join the main Earth ground in a star connection at one central point using thick wire

5.2 System Wiring

This section discusses wiring recommendations applicable to the overall system as opposed to the coupling of particular components.

5.2.1 Wire Gauge

As wire diameter decreases (increased gauge), impedance increases. Higher impedance wire will broadcast more noise than lower impedance wire. Therefore, when selecting the wire gauge, it is preferable to select lower gauge (i.e. larger diameter) wire. This recommendation becomes more critical as the cable length increases. Use the following table to select the appropriate wire size to use in your application.

Table 6

Current (A)	Minimum wire size (AWG)
10	#20
15	#18
20	#16
35	#14
45	#12
60	#10
80	#8
120	#6

5.2.2 Cable Routing

All content sensitive signal wires should be routed as far away from motor power wires as possible. Power wires are a major source of noise and can easily corrupt a nearby signal. This issue becomes increasingly important with longer motor power wire lengths.

5.2.3 Twisted Wires

Twisted wires effectively increasing noise immunity. The successive twists cancel noise transients along the length of the cable. Both signal cables and power cables should be of the twisted and shielded type. Differential signal wires should be twisted as a pair. The combination of twisted pair wires and a differential signal significantly adds to noise immunity. Power wires should be twisted as a group along with the ground (or chassis) wire, if available. For example, the power leads of a brushless motor with a ground wire would all be twisted together as a bundle of 4 wires.

5.2.4 Cable Shielding

All signal wires should be bundled and shielded separately from drive power and motor power wires. Power wires should also be bundled and shielded. When grounding a shield, the rule-of-thumb is to do so at the 'source' of power while leaving the other shield end open. For example, in the case of motor power wires, this would be the drive side. Ideally, twisted pairs should be individually shielded and isolated from the outer shield, which encompasses all wires within the cable. However, since this type of stringent shielding practice is often not required, typical cables do not provide isolation between inner and outer shields.

5.3 Grounding Guidelines & Noise Prevention

Good grounding practices help reduce the majority of noise present in a system. Therefore, this section covers both grounding guidelines and other noise prevention techniques.

5.3.1 System Grounding

All common grounds within an isolated system should be tied to PE through a 'single' low resistance point; that is, a central point grounding should always be carried out. For example, if the power supply ground is pulled to PE, as shown in Figure 3, then no other point common to the power supply ground (such as signal ground) should be connected to PE at a separate location. Avoiding such repetitive links to PE will prevent ground loops, which are a frequent source of noise. Central point grounding should also be applied to cable shielding; shields should be open on one end and grounded on the other. Close attention should also be given to chassis wires. For example, motors are typically supplied with a chassis wire. If this chassis wire is connected to PE, but the motor chassis itself is attached to the machine frame, which is also connected to PE, a ground loop will be created.

Wires used for grounding should be of a heavy gauge and as short as possible. Unused wiring should also be grounded when safe to do so since wires left floating can act as large antennas, which contribute to EMI.

5.3.2 Ferrite Suppression Cores

In addition to the recommendations given above (Section 5.2), ferrite suppression cores (also know as torroids) can further help reduce the effects of EMI. Although unnecessary for many systems, ferrite cores can play a critical role in systems with higher bus voltages (> 200 VDC). Ferrite cores are used at the drive side of a motor power cable where the motor wire leads are wrapped 2-5 times around the core as a group (common mode). Case ground or shield leads should never be wrapped in the ferrite core as this would counteract its effectiveness. If necessary, strip back the shield of the motor power cable such that you have sufficient length to use the ferrite.

Table 7 shows some characteristics of ferrite cores typically used in servo systems. This table can be used to select an appropriate core according to the gauge of the motor power wires. Note that higher impedance will yield more EMI suppression.

Table 7

Wire Gauge (AWG)	Manufacturer	Part Number	Type	Impedance (Ω)		
				10MHz	25MHz	100MHz
28-16	Fair Rite	2631102002	1-Piece Core	103	156	260
28-16	Fair Rite	2643800502	1-Piece Core	-	45	82
28-16	Fair Rite	0443164151	Snap On	-	156	250
20-14	Fair Rite	0431176451	Snap On	130	225	380
20-12	Fair Rite	2643802702	1-Piece Core	-	48	80
12-8	Fair Rite	2643626202	1-Piece Core	-	193	336
12-8	Fair Rite	0431177081	Snap On	145	235	375
10-6	Fair Rite	2643803802	1-Piece Core	-	58	108

5.4 Power Supply

Sufficient capacitance is needed within 1 foot of wire length and in parallel with the power supply of the drive. There should always be at least 1000 µF of capacitance at the power supply. However, some systems may require more. Capacitance is required during braking or deceleration of a motor because energy is transferred back through the drive into the power supply; this is known as regeneration (see Section 10.3 of the Appendix). If the capacitance at the power supply is insufficient in size, its terminal voltage will rise beyond the operating voltage of the drive and, as a result of over-voltage protection, the drive will disable itself and braking/deceleration will cease. To ensure that there is sufficient capacitance, carefully test the system under worst-case braking/deceleration situations while monitoring the bus voltage. If the bus voltage becomes too high, use more capacitance.

If the system cannot be tested or it is unsafe to do so, the required capacitance can be estimated given that the change in energy at the load can be calculated. For more information on making this calculation see Section 10.3 of the Appendix.

As an alternative to additional capacitance, a shunt regulator may be used to bleed off (i.e. dissipate) regenerative energy. Shunt regulators are added in parallel with the DC bus voltage of the drive. For more information on shunt regulators see Section 10.4 of the Appendix.

The distance between the DC power supply of the drive and the drive itself should be as short as possible since the length of cable between the two is a source of noise. If this distance is greater than 3 feet, then a 1000 µF capacitor should be added within 1 foot of the drive. This capacitance stabilizes the voltage supplied to the drive as well as filters noise on the power supply line.

5.5 Drive-to-Motor Wiring

Always verify that the line-to-line inductance of the motor meets the requirements of the drive (see Table 1). Sufficient inductance is required to filter the switching output of the drive and supply the motor with a smooth current waveform. If the drive is operated below its maximum operating voltage, the minimum load inductance requirement may be reduced. In general, most motors will have sufficient inductance; however, motors without a conventional iron core (such a 'basket-wound' or 'pancake') tend to have particularly low inductance.

An inductive filter card may be wired in series with a low inductance motor. Inductive filter cards can also help with noise suppression. In case of relatively long motor cables, placing the filter card at the drive side can help reduce EMI problems. For more information on inductive filter cards see Section 10.6 of the Appendix.

5.5.1 Brushless Motor

A brushless motor will have 3 motor power wires and possibly an additional motor chassis wire. Connect the 3 motor power wires to pins MOTOR A, MOTOR B and MOTOR C of the drive power connector (P2) in any desired order. If you will be using more than 3 Amperes continuous in your application, be sure to use both supplied pins. If a motor chassis wire is provided, connect it to the systems central PE and ensure that the motor chassis itself will be isolated from PE.

5.5.2 Brushed Motor

A brushed motor will have two motor power wires and possibly an additional motor chassis wire. Connect the 2 motor power wires to any two MOTOR pins of the drive power connector (P2). If you will be using more than 3 Amperes continuous in your application, be sure to use both supplied pins. If a motor chassis wire is provided, connect it to the system's central PE and ensure that the motor chassis itself will be isolated from PE.

5.5.3 Motor Feedback

Connect the motor feedback wires to the appropriate pins of the drive I/O connector (P1). Hall sensor inputs can be connected in any particular order. Leave the negative Hall terminals (HALL A-, HALL B-, HALL C-) open for single-ended Hall sensor outputs. Single-ended encoders should use only the positive terminals (I+, A+, and B+) while leaving the other terminals open. If you are using a brushed motor with a tachometer, you may use a programmable analog input for tachometer feedback (provided the tachometer maximum voltage falls within the limits of the analog input).

5.6 Drive-to-Controller Wiring

5.6.1 Reference Input

If you will be using an analog input as a reference/command input, use the differential inputs REF+ IN and REF- IN of the I/O connector (P1). For single ended inputs, use only REF+ IN while leaving REF- IN open. A single ended connection will function correctly in this fashion because REF- IN is connected to an internal reference point (see Figure 1 of Section 2).

5.6.2 Programmable Digital I/O (PDI & PDO)

A controller can interface with the drive through PDIs and PDOs. All single ended PDIs and PDOs are internally pulled to logic high. In order to activate such a PDI, you must pull it to ground. To use a differential PDI as a regular single ended PDI, pull the negative terminal to ground and supply the positive terminal with 0-5 V_{DC}.

5.7 Drive-to-Computer Wiring

The drive supports standard RS232 data transmission. Connect the PC transmit pin (Tx) to the drive receive pin (Rx), the PC receive pin (Rx) to the drive transmit pin (Tx), and connect the PC RS232 ground to the drive signal ground.

5.8 CE-EMC Requirements

Additional installation instructions may be necessary to meet EMC requirements. For reference purposes, the Technical Construction File Number is TCF No. J97001250.007 (Rev 1).

5.8.1 General

- Shielded cables must be used for all interconnect cables to the drive and the shield of the cable must be grounded at the closest ground point with the least amount of resistance.
- The drive's metal enclosure (if available) must be grounded to the closest ground point with the least amount of resistance.

- The drive must be mounted in such a manner that the connectors and exposed printed circuit board are not accessible to be touched by personnel when the product is in operation. If this is unavoidable there must be clear instructions that the drive is not to be touched during operation. This is to avoid possible malfunction due to electrostatic discharge from personnel.
- A Fair Rite model 0443167251 round suppression core must be fitted to the motor cable connector to reduce electromagnetic emissions.
- An appropriately rated Schaffner 2080 series AC power filter in combination with a Fair Rite model 5977002701 torroid (placed on the supply end of the filter) must be fitted to the AC supply of any MOSFET drive system in order to reduce conducted emissions fed back into the supply network.

5.8.2 Analog Input Drives

- A Fair Rite model 0443167251 round suppression core must be fitted to the low-level signal interconnect cables to prevent pickup from external RF fields.

5.9 Filter and Ferrite Supplier

Below is the contact information for a suggested filter and ferrite supplier.

Schaffner

EUROPE (HEADQUARTERS)
Schaffner Holding AG
Nordstrasse 11
CH-4542 Luterbach
Switzerland
Phone: +41 32 6816 626
Fax: +41 32 6816 630

NORTH AMERICA
Schaffner EMC, Inc.
52 Mayfield Ave.
Edison, NJ 08837
Phone: 1-800-367-5566
Phone: 732-225-9533
Fax: 732-225-4789

Fair-Rite

NORTH AMERICA (HEADQUARTERS)
Fair-Rite Products Corp.
PO Box J, 1 Commercial Row, Wallkill, NY 12589
Phone: 888-324-7748
Fax: 888-337-7483

EUROPE
Fair-Rite Europe SAS
3, RN 19
(F-77166)
Grisy-Suisnes, France
Telephone: +33 (0) 1 60 62 71 84
Fax: +33 (0) 1 64 05 96 15

ASIA
Fair-Rite Asia Pte. Ltd. Adress 61 Kaki Bukit Avenue 1
#03-38 Shun Li Industrial Park
Singapore 417943
Telephone: 65-6846 1998
Fax: 65-6846 1918

5.10 CE-LVD Requirements

Instructions Necessary for Meeting LVD Requirements

The servo drives covered in the LVD Reference report were investigated as components intended to be installed in complete systems that meet the requirements of the Machinery Directive. In order for these units to be acceptable in the end users equipment, the following conditions of acceptability must be met:

A. European approved overload and over current protection must be provided for the motors as specified in section 7.2 and 7.3 of EN60204.1.

B. A disconnect switch shall be installed in the final system as specified in section 5.3 of EN60204.1.

C. All drives that do not have a grounding terminal must be installed in, and conductively connected to a grounded end use enclosure in order to comply with the accessibility requirements of section 6, and to establish grounding continuity for the system in accordance with section 8 of EN60204.1.

D. A disconnecting device that will prevent the unexpected start-up of a machine shall be provided if the machine could cause injury to persons. This device shall prevent the automatic restarting of the machine after any failure condition shuts the machine down.

E. European approved over-current protective devices must be installed in line before the drive; these devices shall be installed and rated in accordance with the installation instructions (the installation instructions shall specify an over current protection rating value as low as possible, but taking into consideration inrush currents, etc.). Drives that incorporate primary fuses do not need to incorporate over current protection in the end users equipment.

These items should be included in your declaration of incorporation as well as the name and address of your company, description of the equipment, a statement that the drives must not be put into service until the machinery into which they are incorporated has been declared in conformity with the provisions of the Machinery Directive, and identification of the person signing.

6 SETUP INSTRUCTIONS

Setup and configuration of all DigiFlex drives is done strictly through software. This section will discuss how this software can be acquired and installed. For additional help on using the software refer to the software help content.

6.1 Software Setup

DigiFlex drives use the DriveWare300 application program for setting up and configuring the drive. This application is readily available online at the Advanced Motion Controls website (or contact us directly for information on how to obtain this software). This application can be downloaded as a compressed .zip file. If you don't already have an application for uncompressing such file types, you'll need to download one (also freely available online). Once the .zip file has been downloaded, uncompress it and run the software setup application. Complete the installation process and then run the resulting software.

Be sure to view the installation notes. These notes are particularly important if you are running the latest version of DriveWare300 with an older drive. In some situations a firmware update will be required before you can correctly configure a drive.

Note that you can run DriveWare300 without having a drive connected, however, the oscilloscope tool will not be available. When opening DriveWare300 without a drive, open an existing project file or use the default file provided with the software.

7 THERMAL CONSIDERATIONS

The ZDCR300 drive has two sources of heat generation: heat generated by the internal logic and heat generated by the power output stage. The base plate temperature change caused by these two sources is different due to the internal construction of the drive. Both heat sources are discussed below with all thermal impedance values being relative to temperatures as seen by the drive in an open, ambient, environment. Note that the drive uses a thermal sensor, located near the power output stage, to measure heat sink temperature changes.

7.1 Internal Logic

The thermal impedance of the internal logic section is approximately

$$Z_L = 5.1\ °\text{C/Watt},$$

with the heat generation of the logic section given by

$$W_L = 2.4 \text{ Watts} + [\text{Heat Dissipated in I/O Circuit}] \text{ Watts}.$$

The heat dissipation in the I/O circuit can be calculated from the current through the input and output impedances. This is typically very small and negligible. Thus, the temperature change due to the logic circuit is approximately

$$\Delta T_L = Z_L \times W_L = 12.24\ °\text{C}.$$

As a result, a powered but disabled ZDCR300 can be expected to reach a temperature of about 12 °C above ambient.

7.2 Power Output Stage

The temperature change due to the power output stage is given by

$$\Delta T_O = Z_O \times W_O,$$

where the thermal impedance of the power output stage is approximately

$$Z_O = 4.3\ °\text{C/Watt}.$$

However, unlike with the internal logic, the heat generation of the power output stage, $W_{O,}$ is not a constant value and varies depending upon the output current and bus voltage of the drive as given in Figure 4. To calculate ΔT_O simply extract the appropriate value of W_O from Figure 4 and then multiply it by Z_O.

Example

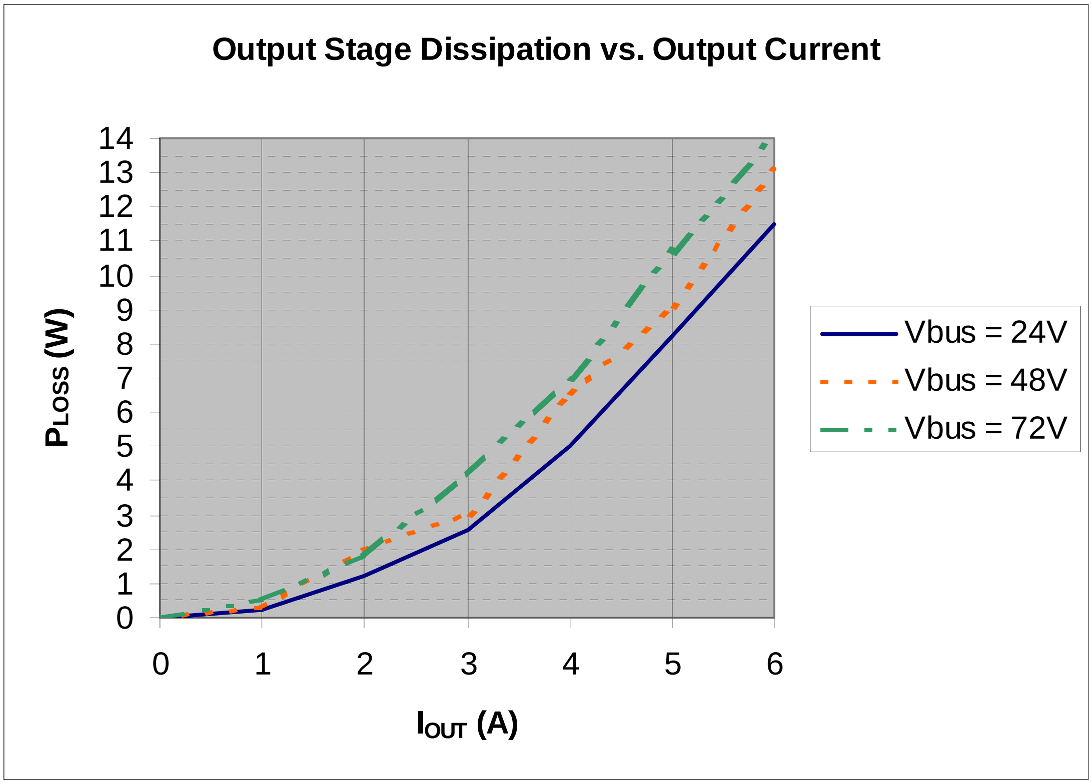
A system with V_{bus} = 24 V_{DC} and I_{out} = 5 A results in W_O = 8.5 Watts. Hence, the temperature change due to the power output stage is:

$$\Delta T_O = Z_O * W_O = 36.55\ °\text{C}$$

Thus, the total base plate temperature change ($\Delta T_L + \Delta T_O$) is approximately 48.8 °C. Hence, in a 25 °C ambient the drive would reach 73.8 °C and shut down due to drive over temperature (>65 °C). In this situation, additional heat sinking and/or cooling is required such that the base plate temperature stays below 65 °C to avoid over-temperature drive shutdown.

The thermal impedance of the power output stage can be reduced by using additional heat sinking and/or cooling. For example, an additional heat sink, of dimensions 2.1 x 2.1 x 0.4 inches, clamped to the existing heat sink can reduced Z_O to 3.8 °C/Watt whereas a 110 CFM fan placed near the drive (within 1 foot) can reduced Z_O to 1.13 °C/Watt.

Figure 4


Output Stage Dissipation vs. Output Current
P_{LOSS} (W)
I_{OUT} (A)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Vbus = 24V
Vbus = 48V
Vbus = 72V

8 Custom Drives

If an application requires a drive in a different form, or if custom labeling is desired, a custom drive may be possible.

To request information regarding custom products, contact a local Advanced Motion Controls representative or the factory directly.

9 WARRANTY INFORMATION

ALL RETURNS (WARRANTY OR NON-WARRANTY) REQUIRE THAT THE CUSTOMER FIRST OBTAIN AN RMA NUMBER FROM THE FACTORY.

RMA number requests may be made by telephone at (805) 389-1935, by fax at (805) 389-1165 or via our web site, http://www.a-m-c.com

ADVANCED MOTION CONTROLS warrants its products to be free from defects in workmanship and materials under normal use and is limited to replacing or repairing at its factory any of its products which within one year after shipment are returned to the factory of origin, transportation charges prepaid, and which are determined to be defective. This warranty supersedes all other warranties, expressed or implied, including any implied warranty or fitness for a particular purpose, and all other obligations or liabilities on ADVANCED MOTION CONTROLS' part and it neither assumes nor authorizes any other person to assume for the seller any other liabilities in connection with the sale of the said articles. The original warranty period is not extended by the above-mentioned provisions for any replaced or repaired articles. This warranty shall not apply to any of ADVANCED MOTION CONTROLS' products that have been subjected to misuse, negligence, accident, or modification by the user.

10 Appendix

The information in this appendix is intended to be generic and is not specific to any one product. As a result, some sections may not pertain to the drive intended for this installation manual. Read the beginning of each section to know if it applies your product. Furthermore, refer to the product datasheet when relating your product to examples which use product specific ratings.

10.1 Isolation

In systems where an AC line is involved, there needs to be isolation between the AC line and the signal pins on the drive. This applies to all systems except those that use a battery as a power supply. If there is no isolation, the drive will immediately fail when the drive signal ground is pulled to earth ground. There are two options for isolation:

1. The drive can have built in electrical isolation.
2. The power supply can provide isolation (e.g. a battery or an isolation transformer).

The system must have at least one of these options to operate safely.

10.1.1 Drive With Isolation

Some Advanced Motion Controls drives come with standard electrical isolation, others have isolation as an option, and some do not have isolation. To determine if an Advanced Motion Controls' drive has isolation refer to the functional block diagram (Figure 1, Section 2). The isolation will be indicated by a dashed line through the functional block diagram and labeled as isolation. If there is no dashed line, through the functional block diagram, separating power ground from signal ground the drive does not have isolation.

The following are *some* of the Advanced Motion Controls drives that come standard with isolation:

- Products that are rated to 400 VDC.
- Drives that take AC line voltage for power.

10.1.2 Power Supply With Isolation

Either a battery or power supply that uses a isolation transformer to isolate the AC line voltage from the power supply ground. This allows both the power ground on an isolated power supply and the signal ground on a non-isolated drive to be safely pulled to earth ground. Always use an isolated power supply if there is no isolation in the drive

10.2 Power Supply Sizing & Selection

A system will need a certain amount of voltage and current to operate properly. If the power supply has too little voltage/current the system will not perform adequately. If the power supply has too much voltage the drive may shut down because of over voltage or worse, the drive and/or motor may be damaged. The processes of calculating the voltage and current requirements are described below.

10.2.1 Selecting the Supply Voltage

The ideal voltage is defined by the following constraints:

- Upper Constraints
  - Drive over voltage limit
  - Shunt regulator voltage (if available)
- Lower Constraints
  - System voltage requirements

- o Drive under voltage limit

Figure 5 illustrates the constraints when selecting a power supply voltage for a drive with power specification as shown in Table 8 and for a system that requires 100 V_{DC} to operate.

Figure 5: In this case the acceptable power supply voltage is between 110V and 170V.

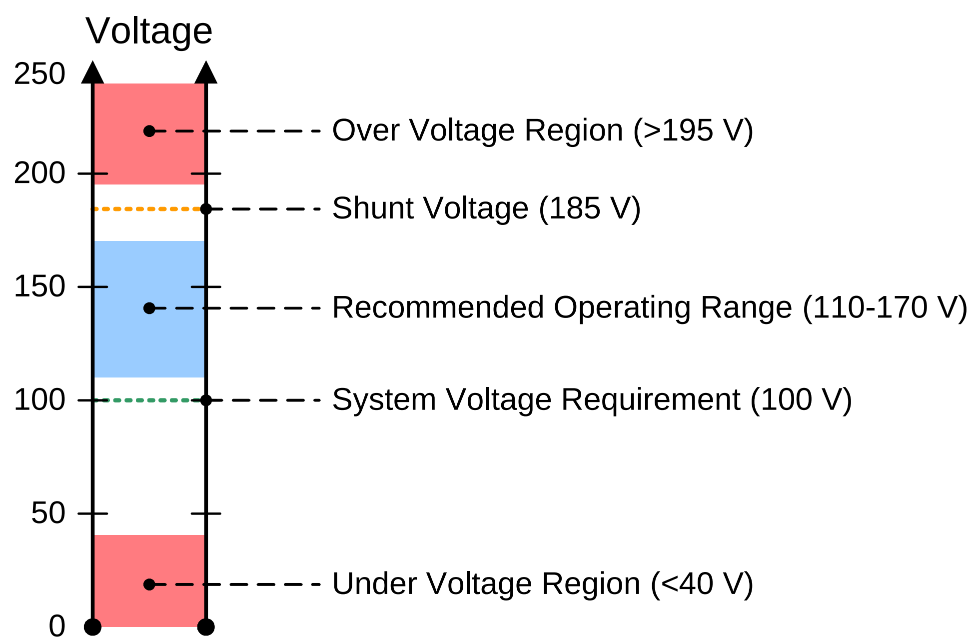


Table 8

Power Specification	Value
Under Voltage	40 V
Over Voltage	195 V

10.2.2 Calculations

Over Voltage – The over voltage level on Advanced Motion Controls' drives can be found in the drive data sheet. In the example from Table 8 the data sheet would state that the over voltage shut down point is 195 VDC.

Shunt Regulator Voltage – From Figure 5, a shunt regulator was chosen with a 185 VDC shunt voltage. The purpose of a shunt regulator is to clamp the power supply voltage so it doesn't exceed the drive over voltage levels during regeneration. See Section 10.3 (Regeneration) to determine if a shunt regulator is required and how to select the correct voltage.

System Voltage Requirement – The system voltage requirement is based on the motor properties and how fast and hard the motor is driven. The system voltage requirement is equal to the motor voltage required to achieve the move profile. The motor voltage is determined as

$$V_M = (K_E \cdot S_M) + (I_M \cdot R_M), \qquad (9.1)$$

Where

V_M Motor Voltage (V),

I_M Motor Current (A) (use the maximum current expected for the application),

K_E Motor Back EMF Constant,

R_M Motor Line to Line Resistance (Ω),

S_M Motor Speed (use the maximum speed expected for the application).

If I_M is not known you can use the maximum current rating of the motor or drive or you can calculate it as

$$I_M = \frac{\text{Torque}}{K_T}, \tag{9.2}$$

where K_T is the motor torque constant.

Keep in mind that the calculated value for V_M is the minimum voltage required to complete moves at the desired speed and torque. There should be at least 20% head room between the calculated value and the actual power supply voltage to allow for machine changes such as increased friction due to wear, change in load, increased operating speed and other changes.

Under Voltage Limit – The under voltage level on Advanced Motion Controls drives can be found in the drive data sheet. In the example from Table 8 the data sheet would state that the under voltage shut down point is 40 VDC.

Acceptable Power Supply Voltage – The power supply voltage needs to be at least 20% above the system voltage requirement and at least 10% below the lowest value of the following:

- Shunt regulator voltage.
- Drive over voltage.
- Power supply over voltage.

10.2.3 Selecting the Supply Current

The power supply current rating is based on the maximum current that will be required by the system. If the power supply provides power to more than one drive then the current requirements for each drive should be added together. Due to the nature of PWM drives the current into the drive does not always equal the current out of the drive, but the "power in" is approximately (minus the power losses in the drive) equal to the "power out". Use the following equation to calculate the drive current requirements based on the motor current requirements.

$$I_{PS} = \frac{V_M \cdot I_M}{V_{PS} \cdot (0.98)}, \tag{9.3}$$

Where

I_{PS} Power Supply Output Current (A).

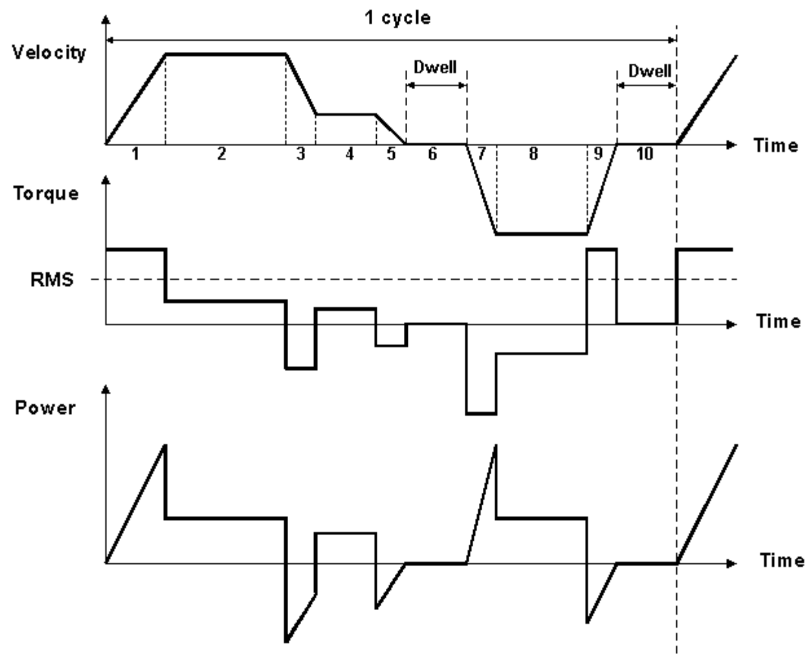
V_{PS} Nominal Power Supply Voltage (V).

I_M Motor Current (A) from Eq. (9.2).

V_M Motor Voltage (V) from Eq. (9.1).

Use values of V_M and I_M at the point of maximum power in the move profile (when $V_M \times I_M$ = max). This will usually be at the end of a hard acceleration when both the torque and speed of the motor are high (see Figure 6).

Figure 6: Power is equal to Torque x Velocity. V_M and I_M should be chosen where power is at a maximum.



Note: The only time the power supply current needs to be as high as the drive output current is if the move profile requires maximum current at maximum velocity. In many cases however maximum current is only required at start up and lower currents are required at higher speeds.

10.3 Regeneration

During motor deceleration or a downward motion of the motor load, conversion of the system's mechanical energy (kinetic and potential) will be regenerated via the servo drive back to the supply in the form of electrical energy.

This regenerative process can charge the capacitors in the power supply to potentially dangerous voltages or voltages that may cause a drive over-voltage shutdown. Consequently, power supplies should have sufficient capacitance to absorb this energy without causing an over-voltage fault. If it is not practical to supply enough capacitance, use of a "shunt regulator" may be necessary to dissipate the kinetic and potential energy of the load. The shunt regulator is connected to the DC power supply to monitor the voltage. When a preset trip voltage is reached, a power resistor R is connected across the DC power supply by the shunt regulator circuit to discharge the power supply capacitor. The electric energy, stored in the capacitor, is thereby transformed into heat (I^2R).

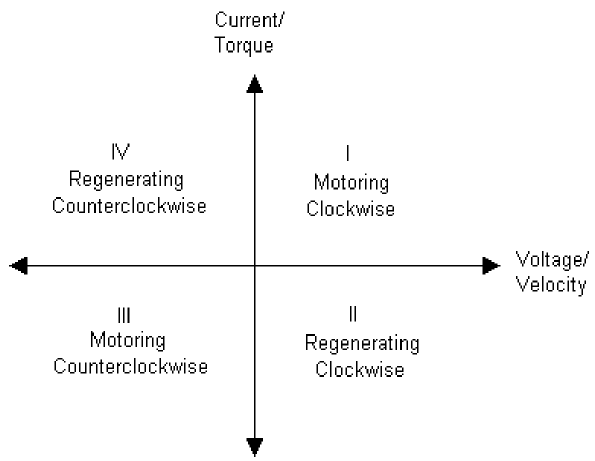
10.3.1 Calculations

The voltage rise on the power supply capacitors (assuming no shunt regulator) can be calculated according to a simple energy balance equation. The amount of energy transferred to the power supply can be determined through

$$E_i = E_f \, , \tag{9.4}$$

where E_i represents initial energy and E_f represents final energy. These energy terms can be broken down into the approximate mechanical and electrical terms. Note: use the metric (kg-m-s) system of units for calculation.

Figure 7: Four quadrant operation. Regeneration occurs when Torque and Velocity polarity are opposite.



I	Torque +	Velocity +	No Regen
II	Torque -	Veolcity +	Regen
III	Torque -	Velocity -	No Regen
IV	Torque +	Velocity -	Regen

The initial and final energy of Eq (9.4) can be separated into capacitive, kinetic, and potential energy. The energy equations for these individual components are as follows:

$$E_c = \frac{1}{2} C V_{nom}^2 , \tag{9.5}$$

where E_c is the energy stored in a capacitor in joules (J), C is the size of the capacitor in Farads (F), and V_{nom} is the nominal bus voltage of the system in volts (V).

$$E_r = \frac{1}{2} J \omega^2 , \tag{9.6}$$

where E_r is the kinetic (mechanical) energy of the load in joules (J), J is the inertia of the load in kg-m^2, and ω is the angular velocity of the load in radians per second (rad/s).

$$E_p = mgh , \tag{9.7}$$

where E_p is the potential mechanical energy in Joules (J), m is the mass of the load in kilograms (kg), g is gravitational acceleration (9.81m/s^2), and h is the vertical height of the load in meters (m).

Similar equations can be applied to linear motor system.

During regeneration the kinetic and potential energy will be stored in the power supply's capacitor. To determine the final power supply voltage following a regenerative event, the following equation may be used for most requirements (see below for variable definitions):

$$\left(E_c + E_r + E_p\right)_i = \left(E_c + E_r + E_p\right)_f , \tag{9.8}$$

$$\frac{1}{2}CV_{nom}{}^{2}+\frac{1}{2}J\varpi_{i}{}^{2}+mgh_{i}=\frac{1}{2}CV_{f}{}^{2}+\frac{1}{2}J\varpi_{f}{}^{2}+mgh_{f}\ . \tag{9.9}$$

Which simplifies to

$$V_{f}=\sqrt{V_{nom}{}^{2}+\frac{J}{C}\left(\varpi_{i}{}^{2}-\varpi_{f}{}^{2}\right)+\frac{2mg\left(h_{i}-h_{f}\right)}{C}}\ . \tag{9.10}$$

The V_f calculated must be below the power supply capacitance voltage rating and the drive over-voltage limit. If this is not the case, a shunt regulator is necessary. Alternatively, capacitance can be added to the system, in order to increase C and hence reduce V_f. However, adding capacitance can often be cost and size prohibitive. A shunt regulator is sized in the same way as a motor or drive i.e. continuous and RMS power dissipation must be determined. The power dissipation requirements can be calculated from the application move profile (see Figure 6).

10.3.2 Special Case

Continuous regeneration – If the application requires continuous regeneration (more than a few seconds) then the shunt regulator may not be sufficient to dissipate the regenerative energy. Please contact Advanced Motion Controls for possible solutions to solve this kind of application. Some examples:

- Web tensioning device
- Electric vehicle rolling down a long hill
- Spinning mass with a very large inertia (grinding wheel, flywheel, centrifuge)
- Heavy lift gantry

10.4 Shunt Regulators

Advanced Motion Controls offers a variety of shunt regulators for servo drives. Shunt regulators are sometimes necessary because braking or deceleration of a mechanical load results in its energy being fed back into the power supply, which causes a rise in bus voltage. This phenomenon is known as regeneration (see Section 10.3). If the charge reaches the drive's over-voltage shutdown point, motor control and braking will cease. To ensure smooth deceleration of large inertial loads the use of a shunt-regulator is recommended. Verify the need for a shunt regulator by operating the servo under the worst-case braking and deceleration conditions. If the drive shuts off due to over-voltage a shunt regulator is necessary

Shunt regulators operate by dissipating energy through a resistor placed in parallel with the DC bus voltage. When the bus voltage reaches the shunt voltage, as specified by the shunt regulator, a voltage comparator unit turns on an electronic switch that connects the shunt resistor across the DC bus. This power resistor dissipates the energy from the DC bus. After the bus voltage is reduced to less than the shunt voltage setting the resistor is disconnected from the bus. A small hysteresis loop allows time between switching.

When choosing a shunt regulator, choose one with a shunt voltage that is greater than the DC bus voltage of the application but less than the over-voltage shutdown of the drive.

10.5 Voltage Ripple

For the most part Advanced Motion Controls drives are unaffected by voltage ripple from the power supply. The current loop is usually fast enough to compensate for 60Hz fluctuations in the bus voltage, and the components in the drive are robust enough to withstand all but the most extreme cases. Peak to peak voltage ripple as high as 25 V is acceptable.

There are some applications where the voltage ripple can cause unacceptable performance. This can become apparent where constant torque or force is critical or when the bus voltage is pulled low during high speed and high current applications. If necessary, the voltage ripple from the power supply can be reduced, either by switching from single phase AC to three phase AC, or by increasing the capacitance of the power supply.

10.5.1 Calculations

The voltage ripple for a system can be estimated using the equation

$$V_R = \frac{I_{PS}}{C_{PS}} F_f \, , \tag{9.11}$$

where V_R is the voltage ripple, C_{PS} is the power supply capacitance, and F_f is the frequency factor.

The power supply capacitance can be estimated by rearranging the above equation to solve for the capacitance C_{PS} as

$$C_{PS} = \frac{I_{PS}}{V_R} F_f \, . \tag{9.12}$$

The variables for this equation are defined below.

$$F_f = \frac{0.42}{f} \, , \tag{9.13}$$

where f is the AC Line Frequency in hertz (Hz). Note that for half wave rectified power supplies $f = f / 2$. I_{PS} is the power supply output current which, if not known, can be estimated by using information from the output side of the servo drive as given below.

$$I_{PS} = \frac{V_M \cdot I_M}{V_{PS} \cdot (0.98)} \, , \tag{9.14}$$

where I_M is the current through the motor as defined by Eq. (9.2), V_{PS} is the nominal power supply voltage in volts (V), and V_M is the motor voltage defined as

$$V_M = (K_E \cdot S_M) + (I_M \cdot R_M) \, . \tag{9.15}$$

In Eq. (9.15), K_E is the motor back EMF constant (also known as the voltage constant) in volts per thousands of RPM (V/kRPM), S_M is the motor speed in thousands of RPM (kRPM), R_M is the line-to-line resistance of the motor in ohms (Ω), and I_M is defined by Eq. (9.2).

10.6 Filter Cards

Advanced Motion Controls offers a selection of inductive filter cards. These filters contain two inductors for single-phase loads and three inductors for three phase loads. Filter cards have two typical applications:

1. To increase the inductance to meet the minimum load inductance requirement of Advanced Motion Controls' drives. Some motors have inductances that are less than the minimum load inductance requirement for the drive. For example "basket-wound" and "pancake" motors do not have a conventional iron core so the winding inductance is usually less than 25 µH. For this type of application the filter card should be sized so the total inductance of the motor plus filter card meets or exceeds the inductance requirement of the drive. The filter card must also be rated to the required current.
2. To reduce the dV/dt of the motor outputs. The main source of emitted drive noise is the high dV/dt (typically about 1 V per nanosecond) of the drive's output power stage. Unfiltered motor outputs can introduce noise in analog and digital signals. For applications with noise sensitive devices e.g. video cameras, magnetic or capacitive sensors the use of an external inductive filter card may reduce emitted noise.

10.7 PCB Design

This section will give some general recommendations regarding the design of the PCB to which a drive, or drives, will be mounted. Specific information, such as minimum trace distances and widths, will not be covered since these parameters will vary according to the design requirements of an application (ex. UL compliance).

10.7.1 Signal & Power Traces

Whenever possible, route low-level signals away from high power traces and noise sources such as power devices and power traces. Also, ensure that high power traces will be large enough to handle the current that will be drawn by the drive.

10.7.2 Recommended Components

A DC bus capacitor should be added near the power input connector to reduce voltage ripple. Select an aluminum electrolytic capacitor rated for at least 100 VDC and 33 µF.

GLOSSARY

Brushed (DC Motor): Refers to a brushed DC, or simply brushed, motor which uses conductive brushes for commutation; the brush makes a physical contact between the stator and the rotor. Brushed DC motors can be split into two categories: standard DC or permanent magnet DC (PMDC). Standard DC motors have an electromagnet, or winding, on the rotor and another electromagnet on the stator, often referred to as the field winding. The stator winding and field winding can be wired in series or in parallel, resulting in different motor characteristics. Standard DC motors tend not be used in servo systems due to their non-linearity. PMDC motors replace the field winding with a permanent magnet, resulting in motor characteristics, which are more linear.

Brushless (Motor): Refers to a brushless permanent magnet, or simply brushless, motor. Brushless motors are part of the AC synchronous motor family with permanent magnets on the rotor and multiphase windings on the stator. They are available as rotary or linear motors. Control over the torque angle between the electromagnetic stator field and magnetic rotor field allow the motor to be commutated. Brushless motors have several advantages over brushed motors including no maintenance requirements, longer life spans, higher efficiency, higher power density, and lower electrical noise. For these reasons, brushless motors are often the motor of choice in high performance servo systems.

Commutation: The method used to maintain a phase relationship between the stator and rotor magnetic field in order to obtain optimal torque production.

Controller: The system function that is responsible for the final output. The controller can be a separate device or be part of the drive. It can be as complex as a processor-based device that controls the multi-axis position trajectories, or as simple as a potentiometer that sets the speed of the motor.

Differential Signal: When two wires are used to transmit a single signal. In general, one wire transmits the signal whereas the other transmits its complement. Signals transmitted in this manner are much more immune to noise than when a single wire is utilized.

Drive: The servo drive, or simply drive, is the component of a servo system that translates a low power input (command) signal to a higher power output. This input is generally used to adjust a quantitative attribute of a motor such as torque, velocity, or position.

Electrical Revolution/Cycle: An electrical revolution corresponds to one cycle of phase-to-phase back EMF from the motor. In one mechanical revolution, there are as many electrical revolutions as there are pole pairs.

EMI / Electro-Magnetic Interference: Noise present on a signal due to an electromagnetic source. The source is generally in the form of a high frequency oscillating potential.

Encoder: A feedback device used to measure the velocity or relative position of a mechanical load. These devices typically utilize a photo emitter and detector to encode two sets of tracks on a glass disk. These tracks are identical in terms of the number of lines per revolution but slightly offset. The offset allows for increased effective resolution. A reference or index track, consisting of one line per revolution, is also typically supplied.

Ferrite: Ferrite suppression cores, known simply as ferrites or torroids, are used to suppress the electromagnetic field radiating from a source of EMI.

Hall (Effect) Sensors: A feedback device used in brushless motors to allow an external device to commutate that motor. Hall sensors are typically found in one of two forms: 120º or 60º degree separation. However, 120º degree separation is the most common. Hall sensors consist of three sensors on the stator of a motor that detect 6 different positions of the rotor over each electrical cycle.

Isolation: Used in this documentation to express the fact that one reference point is electrically isolated from another reference point. That is, all signals on one side of an isolation barrier will be taken relative to one point whereas all signals on the other side of the isolation will be taken relative to a different point.

Kinetic Energy: The mechanical energy acquired by a mass due to motion.

PE / Protective Earth: The point often supplied on the chassis of an electronic unit with the intention of it being tied to Earth ground for the purpose of safety.

Poles: The magnets or electromagnets in a motor are often referred to as pole pairs. A motor must have at least two poles (one pole pair) to function but most motors have multiple pairs. A higher number of poles is typically found in higher power motors.

Potential Energy: The mechanical energy acquired by a mass due to a change in height.

PMDC / Permanent Magnet Direct Current (Motor): See Brushed (Motor).

PWM / Pulse Width Modulation: When a signal is varied/modulated by changing the width (or duty cycle) of repetitive pulses in the signal. In terms of motion control, this often refers to a square waveform of constant frequency with the square pulses varying in width.

Regeneration: The phenomenon of having the mechanical energy of a load of a servo system transferred to the power supply of that servo system in the form of electrical energy.

Servo: To control the motion of a mechanical load.

Shunt Regulator: A component often found in servo systems to help dissipate the electric energy delivered back to a power supply due to regeneration.

Tachometer: A feedback device used to measure the velocity of a mechanical load. Essentially a small rotary generator attached to the load that outputs a voltage dependent upon the speed of the load.

Torroid: See Ferrite.